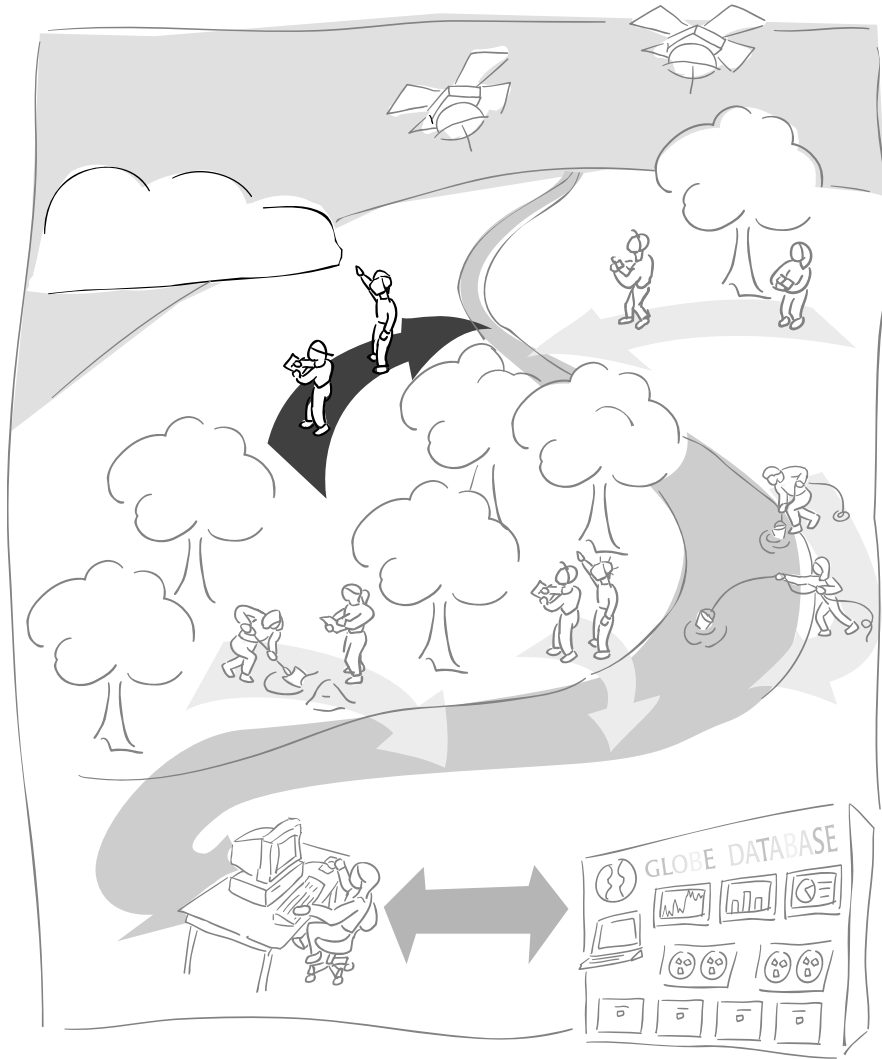


Earth System Science Investigation



A GLOBE® Learning Investigation



Earth System Science Investigation



Protocols

Daily, Seasonal Measurements

Basic

Budburst

Bi-weekly, Seasonal Measurements

Basic

Green-Up

Green-Down

Optional Measurements

Ruby-Throated Hummingbirds (daily or bi-weekly, seasonal)

Phenological Gardens (daily or bi-weekly, seasonal)

Suggested Sequence of Activities

- Read the Introduction to become familiar with seasons, phenology, and studying Earth system science at different space and time scales.
- If you want to do the *Phenological Gardens Protocol*, the best time to plant your garden is in the spring or autumn. You must wait a year to collect data.
- *What Can We Learn About Our Seasons, What Are Some Factors That Affect Seasonal Patterns, How Do Seasonal Temperature Patterns Vary Among Different Regions of the World* learning activities introduce students to characteristics and patterns of seasons.
- *Green-Up Cards, A Sneak Preview to Budburst*, and a *First Look at Phenology* learning activities set the stage for taking the phenology measurements.
- Choose one of the Phenology Protocols to start (*Green Down* or *Hummingbirds* in the fall; *Budburst, Green Up*, or *Hummingbirds* in the spring); Phenological Gardens throughout the year)
- *A Beginning Look at Photosynthesis* and *Investigating Leaf Pigments* learning activities help students better understand the process of photosynthesis.
- *Global Patterns in Green-Up and Green-Down* and *Limiting Factors in Ecosystems* allow students to explore global trends in green-up and green-down and to explore why these patterns occur in different ecosystems.
- *Modeling the Reasons for Seasonal Change* and *Seasonal Change on Land and Water* learning activities helps students understand factors that cause seasonal patterns.
- *Connecting the Parts of the Study Site, Representing the Study Site in a Diagram, Using Graphs to Show Connections, Diagramming the Study Site for Others*, and *Comparing the Study Site to One in Another Region* learning activities allow students to explore Earth system connections at the local scale.
- *Defining Regional Boundaries* and *Effects of Inputs and Outputs on a Region* learning activities allow students to explore Earth system connections at the regional scale.
- *Your Regional to Global Connections* and *Components of the Earth System Working Together* learning activities allow students to explore Earth system connections at the global scale.



Table of Contents



Introduction*

Why Study Earth System Science?*	Introduction 1
The Big Picture*	Introduction 2
The Earth as a System*	Introduction 9
The Seasonal Cycle*	Introduction 9
The Earth System through the Seasonal Cycle*	Introduction 17
The Earth System on Different Spatial Scales*	Introduction 28



Phenology Protocols

Introduction
Budburst Protocol
Green-Up Protocol
Green-Down Protocol
Ruby-throated Hummingbird Protocol**
Lilac Phenology Protocol*
Phenological Gardens Protocol**
Seaweed Reproduction Phenology Protocol*
Arctic Bird Migration Monitoring Protocol*



Learning Activities: Seasons and Phenology*

Introduction*
Seasons*
Seasons and Phenology Introduction*
S1: What Can We Learn About Our Seasons?*
S2: What Are Some Factors That Affect Seasonal Patterns?*
S3: How Do Seasonal Temperature Patterns Vary Among Different Regions of the World?*
S4: Modeling the Reasons for Seasonal Change*
S5: Seasonal Change on Land and Water*
Phenology*
P1: Green-up Cards*
P2: A Sneak Preview of Budburst*
P3: A First Look at Phenology*
P4: A Beginning Look at Photosynthesis*
P5: Investigating Leaf Pigments*
P6: Global Patterns in Green-up and Green-down*
P7: Temperature and Precipitation as Limiting Factors in Ecosystems*



* See the full e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.

** Separate print version available on request to schools in the areas where the protocol may be conducted. The protocol and related material are also available in the e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.



Learning Activities: Exploring the Connections*

Introduction*

Local Connections*

LC1: Connecting the Parts of the Study Site*

LC2: Representing the Study Site in a Diagram*

LC3: Using Graphs to Show Connections*

LC4: Diagramming the Study Site for Others*

LC5: Comparing the Study Site to One in Another Region*

Regional Connections*

RC1: Defining Regional Boundaries*

RC2: Effects of Inputs and Outputs on a Region*

Global Connections*

GC1: Your Regional to Global Connection*

GC2: Components of the Earth System Working Together*

Appendix

Budburst Site Definition Sheet	Appendix 2
Green-Up and Green-Down Site Definition Sheet.....	Appendix 3
Budburst Data Sheet.....	Appendix 4
Tree and Shrub Green-Up Data Sheet	Appendix 5
Grass Green-Up Data Sheet	Appendix 6
Tree, Shrub, and Grass Green-Down Data Sheet.....	Appendix 7
Ruby-throated Hummingbird (RTHU) Site Definition Data Sheet	Appendix 8
RTHU Hummingbird Sighting Protocol Data Sheet	Appendix 10
RTHU Feeder Visit Protocol Data Sheet	Appendix 12
RTHU Flower Visit Protocol Data Sheet.....	Appendix 14
RTHU Feeder vs. Flower Visit Protocol Data Sheet	Appendix 16
RTHU Flower Species Visit Protocol Data Sheet.....	Appendix 18
RTHU Nesting Report Protocol Data Sheet (U.S. and Canada)	Appendix 20
Clonal and Common Lilac Site Definition Sheet	Appendix 21
Clonal and Common Lilac Data Sheet	Appendix 22
Phenological Gardens Site Definition Data Sheet.....	Appendix 23
Phenological Gardens Data Sheet	Appendix 25
Seaweed Reproductive Phenology Site Definition Data Sheet	Appendix 27
Seaweed Reproduction Phenology Protocol Data Sheet	Appendix 28
Arctic Bird Migration Monitoring Site Definition Data Sheet	Appendix 29
Arctic Bird Migration Monitoring Protocol Data Sheet	Appendix 30
Glossary	Appendix 31

* See the full e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.